

FUNGI ASSOCIATED WITH SOILS COLLECTED BENEATH AND BETWEEN PINYON AND JUNIPER CANOPIES IN NEW MEXICO

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ABSTRACT.—The soil fungal community beneath pinyon (*Pinus edulis* Engelm.) and one-seeded juniper (*Juniperus monosperma* [Engelm.] Sarg.) tree canopies is described and compared with fungi from adjacent interspace soils dominated by blue grama (*Bouteloua gracilis* [H.B.K.] Lag.). Significantly higher organic matter contents and fungal propagule levels were found in soils beneath pinyon and juniper trees than in interspace soils. Soils under pinyon and juniper trees contained similar chemical, physical, and biological properties and, consequently, many groups of fungi in common (64% of the species isolated were common to both). In contrast, soil fungi in adjacent interspace soils were vastly different from those collected in soils beneath pinyon and juniper canopies (44% and 48% species in common, respectively). Soil fungi that were isolated more often from pinyon-juniper soils than from interspace soils included *Absidia* spp., *Beauveria* spp., *Gliocladium* spp., *Mucor* spp., *Penicillium cyclopium*, *P. fasciculata*, *P. frequentans*, *P. restrictum*, *Thamnidium* spp., and *Trichoderma* spp. Soil fungi that were isolated more often in interspace soils than in pinyon or juniper soils included *Aspergillus alutaceus* spp., *A. fumigatus*, some *Fusarium* spp., *Penicillium luteum*, and *P. talaromyces*.

Pinyon (*Pinus edulis* Engelm.) and one-seeded juniper (*Juniperus monosperma* [Engelm.] Sarg.) trees have been reported to accumulate significant amounts of organic matter and nutrients beneath their canopies (Barth 1980, Tiedemann 1987, Klopatek 1987). Although the soil nutrient content directly under pinyon and juniper trees is higher than in interspace soils, growth of other plant species has been reported to be severely inhibited. Armentrout and Pieper (1988), for example, reported that the mean basal cover of grasses located directly beneath pinyon and juniper trees was 3.7% and 0.7%, respectively, while adjacent interspaces contained over 10% grass cover. Low grass cover under pinyon and juniper canopies is caused by a number of factors, including severe shading (Johnsen 1962), litter accumulation that inhibits seed germination (Jameson 1966), interception of precipitation (Gifford 1970), and allelopathy effects (Jameson 1961, Lavin et al. 1968).

Soil fungal populations and composition are related to soil properties as influenced by vegetation (Christensen 1981). Fungal populations, for example, generally increase as organic matter increases (Alexander 1977). Also, Badurowa and Badura (1967) demonstrated

that the composition of litter in a given plant community is the decisive factor in determining the dominant groups of fungi. To date, only limited observations have been reported concerning the changes in the fungal community (i.e., vesicular-arbuscular endomycorrhizae) associated with plant litter under pinyon or juniper trees (Klopatek and Klopatek 1987). The objective of this study was to evaluate the quantitative and qualitative differences in the saprophytic fungal community associated with soils collected beneath pinyon and juniper canopies and to compare them with the fungal community in adjacent blue grama (*Bouteloua gracilis*)–dominated interspace soils.

MATERIALS AND METHODS

Four pinyon and four juniper trees (4–6 m in height) located just east of Santa Fe, New Mexico, were randomly selected for study in August 1989. Soil samples were collected from two of the three zones described by Armentrout and Pieper (1988); zone 1 was located beneath the tree canopy, and zone 2 was well outside the canopy. This soil area (interspace) was dominated by blue grama. At each of the eight trees, four soil subsamples were

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collected randomly from beneath the canopy to a depth of 15 cm with a 5-cm-diameter bucket auger. The four subsamples were mixed (composited) to represent one sample per tree. Four subsamples were also randomly collected and composited from interspace soils occurring adjacent to the tree species. Thus, a total of 16 composite samples were transported in an ice cooler back to the laboratory. At the laboratory, the samples were passed through a 2-mm sieve and stored at 4 C prior to fungal analysis. An aliquot of approximately 500 grams from each soil sample was taken for laboratory chemical (soluble Na, Ca, Mg, and K; available P; total Kjeldahl N [TKN]; organic matter [OM]; pH; and electrical conductivity [EC]) and physical (percent sand, silt, and clay) analysis at the New Mexico State University Soil and Water Testing Laboratory. All methods of chemical and physical analyses have been described previously (Fresquez and Lindemann 1983).

Numbers of soil fungal propagules were estimated by the dilution and plating technique described by Wollum (1982). For population estimates, dilutions were plated in triplicate on rose bengal-streptomycin agar (Martin 1950) and incubated at 27 C for seven days. The numbers of fungal propagules per gram of oven-dry soil are reported. Fungal groups were isolated by placing 1 mL of a 10^{-3} dilution from a 10-g over-dry weight equivalent soil sample in a petri dish, adding cooled rose bengal-streptomycin agar, and swirling for an even distribution. Ten plates were inoculated for each composited soil sample and incubated at 27 C for seven days (Fresquez and King 1989). After incubation, a portion of every colony was transferred to a carrot agar medium by removing a portion of the agar containing hyphal tips. The colony was subcultured on a carrot agar plate to allow for maximum fruiting potential and identification. After a four-day incubation period, the colonies were identified using the taxonomic guides of Barnett and Hunter (1972), Barron (1968), Gilman (1968), and Domsch et al. (1980).

Diversity of fungi may give some insight into the physiochemical conditions of the soil environment, in terms of identifying more productive soils (Fresquez et al. 1990) and/or soils that are physiochemically stressed (Fresquez et al. 1986). Thus, the diversity of fungal

groups among the treatments was estimated using Shannon's index of species diversity, H (Zar 1974):

$$H = - \sum_{i=1}^k p_i \log p_i$$

where p_i = the proportion of fungal group i in the sample, and k = the number of groups. The corresponding test for evenness is

$$J = H/H_{\max}$$

where $H_{\max}$ = the maximum possible diversity.

An estimate of the similarity in the fungal composition among the sample populations was calculated with Sorensen's presence community coefficient (SPCC), which was described by Mueller-Dombois and Ellenberg (1974) as

$$SPCC = 200 C / (A + B)$$

where C is the total number of groups common to two habitats, A is the total number of groups in sample A, and B is the total number of groups in sample B. If the same groups were found in both samples, then the community coefficient would be 100; if the sample had no groups in common, the coefficient would be 0.

Variations in soil chemical properties and in the populations of soil fungi between trees and adjacent interspaces were analyzed using paired t tests at the .05 level. Unpaired t tests were used to compare soil properties and fungal population means between the two tree species at the .05 level.

RESULTS AND DISCUSSION

Significantly higher fungal propagules were found in soils from beneath pinyon and juniper canopies than from interspace soils (Table 1). Other soil fungal groups, such as vesicular-arbuscular endomycorrhizae, have been reported to be higher in soils from pinyon and juniper trees than from interspace soils (Klopatek and Klopatek 1987). The higher number of soil fungal propagules from pinyon and juniper trees was probably due to differences in organic matter (OM) contents, as significantly higher soil OM levels were found under canopies of both pinyon and juniper trees than in interspace soils (Table 2).

TABLE 1. Soil fungal propagules and Sorensen's presence community coefficients associated with a pinyon-juniper plant community in New Mexico.

Soil site	Fungal propagules ($\times 10^3$)	Similarity coefficients			
		Pinyon		Juniper	
		Understory	Interspace	Understory	Interspace
Pinyon understory	518a ¹ A ² (123)		44	64	38
interspace	43b (17)			35	56
Juniper understory	393y A (119)				48
interspace	39z (15)				

¹Means within the same column and tree species followed by the same letter are not significantly different at the .05 level using paired *t* tests (standard deviation).
²Means within the same column followed by the same uppercase letter are not significantly different at the .05 level using unpaired *t* tests.

TABLE 2. Soil (sandy loam) chemical properties associated with a pinyon-juniper plant community in New Mexico.

Soil site	Soluble cations ($\mu\text{g g}^{-1}$)				Phosphorus and nitrogen ($\mu\text{g g}^{-1}$)				OM ¹ (g kg^{-1})	EC ¹ (dS m^{-1})	pH
	Na	Ca	Mg	K	P	NH ₄ -N	NO ₃ -N	TKN ¹			
Pinyon understory	6a ² A ³ (1.8)	188aA (18.8)	23aA (4.9)	32aA (5.08)	9aA (3.63)	3.7aA (1.74)	9.0aA (5.85)	2143aA (649)	49aA (13.3)	0.83aA (0.15)	7.4aB (0.17)
interspace	12a (8.2)	62b (17.5)	11b (5.1)	1b (0.27)	3b (0.83)	1.6a (0.85)	5.0a (0.56)	525b (271)	14b (2.8)	0.44b (0.08)	7.3a (0.22)
Juniper understory	11yA (2.8)	238yA (24.1)	35yA (9.5)	45yA (3.94)	13yA (8.50)	2.8yA (1.68)	10.6yA (3.82)	1989yA (300)	49yA (4.7)	1.13yA (0.21)	7.8yA (0.21)
interspace	9y (4.2)	76z (13.6)	11z (2.1)	3z (0.86)	4y (0.66)	2.0y (0.67)	5.6y (0.74)	598z (208)	16z (2.5)	0.44z (0.07)	7.4z (0.16)

¹TKN (total Kjeldahl nitrogen), OM (organic matter), EC (electrical conductivity).
²Means within the same column and tree species followed by the same letter are not significantly different at the .05 level using paired *t* tests (standard deviation).
³Means within the same column followed by the same uppercase letter are not significantly different at the .05 level using unpaired *t* tests.

Soils with high OM usually have higher fungal populations than soils with low OM concentrations (Alexander 1977). Moreover, the low fungal populations in the soil from the interspaces may be attributed not only to low OM content but also to the more severe environment at the surface of the more exposed interspaces. For example, lower amounts of plant litter mulch lead to higher amounts of exposed soil, higher surface temperatures, and lower soil moisture contents that reduce soil fungal populations (Wicklow 1973).

Other soil properties, such as Ca, Mg, K, and TKN, were significantly higher under pinyon and juniper trees than in interspace soils (Table 2). Many studies have shown that soils under pinyon and juniper canopies contain higher soil nutrient levels, including N, than soils in adjacent interspaces (Barth 1980,

Tiedemann 1987, Thran and Everett 1987, Klopatek 1987). Soil NH₄-N and NO₃-N levels were higher, although not significantly different, in pinyon and juniper soils than in interspace soils. In any case, the conversion of NH₄-N to NO₃-N (nitrification) does not appear to be inhibited. These data agree with Klopatek and Klopatek (1987), who found that nitrification, despite low nitrifier counts, occurred under pinyon and juniper trees. Thus, since soil fungi were found in significantly higher populations directly under pinyon and juniper trees than in interspace soils (Table 1), and since nitrifying bacteria have been reported to be partially inhibited by allelopathic substances directly beneath pinyon and juniper canopies (Klopatek and Klopatek 1987), soil NO₃-N produced under pinyon and juniper trees as compared to interspace soils

may be more a result of heterotrophic rather than autotrophic nitrification. Some soil fungi have been shown to produce significant amounts of nitrate in media containing ammonium as the sole N source (Doxtader and Alexander 1966, Doxtader and Rovira 1968).

A total of 921 fungal colonies representing 40 fungal groups were isolated and identified (Table 3). Although the interspace soils contained the lowest number of species isolated, their species diversity index, which is based on the number of species and relative density, was comparable to the pinyon and juniper data. Usually, soils that contains more OM have higher fungal populations but a lower fungal diversity than soils lower in OM (Dennis and Fresquez 1989, Fresquez et al. 1990). Soils collected from under both pinyon and juniper canopies contained significantly higher fungal populations than interspace soils. However, only the soil collected underneath pinyon trees had a lower fungal diversity index than the soil from the interspace soils.

Soil fungi isolated beneath pinyon and juniper trees were highly similar (64% of the fungi were common to the two soils) in composition (Table 1). The similarity in the types of fungi isolated between these two soils was probably a result of similar OM contents. Also, most soil chemical and physical properties were similar between these two canopy soils. Although these soils contained many fungal species in common, some fungi were associated with pinyon soils more often than juniper: *Absidia* spp., *Mucor* spp., *Penicillium janthinellum*, *P. restrictum*, *Trichoderma* spp., and some *Mycelia sterilia*. *Penicillium restrictum*, *Trichoderma* spp., and *P. cyclopium* dominated the soils collected under pinyon tree canopies. In contrast, fungi that were isolated more often in soils collected underneath juniper trees included *Aspergillus nidulans*, *A. niger*, *Gliocladium* spp., *Mortierella* spp., *P. cyclopium*, *P. fasciculata*, *P. monovorticillata*, *P. nigricans*, and another unidentified *Penicillium* sp. *Penicillium monovorticillata*, *P. nigricans*, and another *Penicillium* sp. isolated from soils collected under juniper canopies were not recovered at all from pinyon soils. *Penicillium fasciculata* and *P. cyclopium* dominated the soils collected below juniper tree canopies.

The soil fungal community composition beneath pinyon and juniper tree canopies

TABLE 3. Composition and distribution of fungal groups associated with a pinyon-juniper plant community. Density of isolates was obtained from ten 1:1000 soil dilution plates.

Fungal groups	Pinyon		Juniper	
	Under-story	Inter-space	Under-story	Inter-space
<i>Absidia</i>				
sp. 1	7	0	1	0
sp. 2	4	0	4	0
<i>Acromonium</i>	0	2	1	0
<i>Aspergillus</i>				
(<i>alutaceus</i>)				
sp. 1	0	3	0	8
sp. 2	0	3	0	0
<i>fumigatus</i>	0	48	0	25
<i>nidulans</i>	0	0	5	0
<i>niger</i>	0	0	3	6
<i>A. sp.</i>	0	0	1	0
<i>Beauveria</i>	1	0	1	0
<i>Chaetomium</i>	0	0	1	0
<i>Chrysosporium</i>	1	1	0	0
<i>Curcularia</i>	0	0	0	3
<i>Fusarium</i>				
sp. 1	3	0	3	3
sp. 2	0	5	3	16
sp. 3	2	0	0	0
sp. 4	0	8	4	3
<i>Gliocladium</i>	6	0	12	0
<i>Idriella</i>	0	1	0	0
<i>Mortierella</i>	0	0	2	0
<i>Mucor</i>	17	0	11	2
<i>Mycelia</i>				
(<i>sterilia</i>)				
sp. 1	1	1	2	0
sp. 2	6	1	0	0
<i>Penicillium</i>				
<i>cyclopium</i>	41	0	75	9
<i>eupenicillium</i>	0	24	0	0
<i>fasciculata</i>	12	5	81	2
<i>frequentans</i>	28	0	27	0
<i>janthinellum</i>	4	10	0	0
<i>lilacinum</i>	2	2	1	4
<i>luteum</i>	1	49	2	5
<i>monovort</i>	0	11	29	8
<i>nigricans</i>	0	0	25	0
<i>restrictum</i>	74	30	13	0
<i>talaramyces</i>	0	6	0	6
<i>P. sp. 1</i>	0	0	22	0
<i>P. sp. 2</i>	4	0	0	0
<i>P. sp. 3</i>	0	1	0	1
<i>Thamnidium</i>	3	0	2	0
<i>Trichoderma</i>	50	0	2	6
Unidentified	1	2	0	0
No. of isolates	268	213	333	107
No. of groups	21	20	26	16
Diversity	0.97	1.04	1.16	1.14
Evenness	0.73	0.80	0.82	0.95

was different from that of interspace soils. Pinyon and juniper soils, for example, contained only 44% and 48%, respectively, of

all species in common with the interspace soils. Soil fungal organisms isolated more often from pinyon and juniper soils than from interspace soils were *Absidia* spp., *Beauveria* spp., *Glocladium* spp., *Mucor* spp., *Penicillium cyclopium*, *P. fasciculata*, *P. frequentans*, *P. restrictum*, *Thamnidium* spp., and *Trichoderma* spp. Most of these fungal organisms are common soil saprophytic fungi. *Beauveria* is an insect parasite (Moore-Landecker 1972) and is probably associated with the higher microarthropod population inhabiting the litter layer under pinyon and juniper canopies (Whitford 1987). In contrast, fungal organisms isolated more often in blue grama-dominated interspace soils than in pinyon or juniper soils were *Aspergillus alutaceus* spp., *A. fumigatus*, some *Fusarium* spp., *Penicillium luteum*, and *P. talaromyces*. *Aspergillus fumigatus* and especially *Fusarium* spp. are characteristic of grassland soils (Christensen 1981) and blue grama-dominated soils in the semiarid Southwest (Fresquez et al. 1988).

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